Grant NGL 50-002-044

SEMI-ANNUAL STATUS REPORT

to

THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Submitted by

The Space Physics Group

University of Wisconsin

December 1975

(NASA-CR-146014) SEMIANNUAL STATUS REPORT (Wisconsin Univ.) 22 p

N76-70830

Unclas

00/98 05636

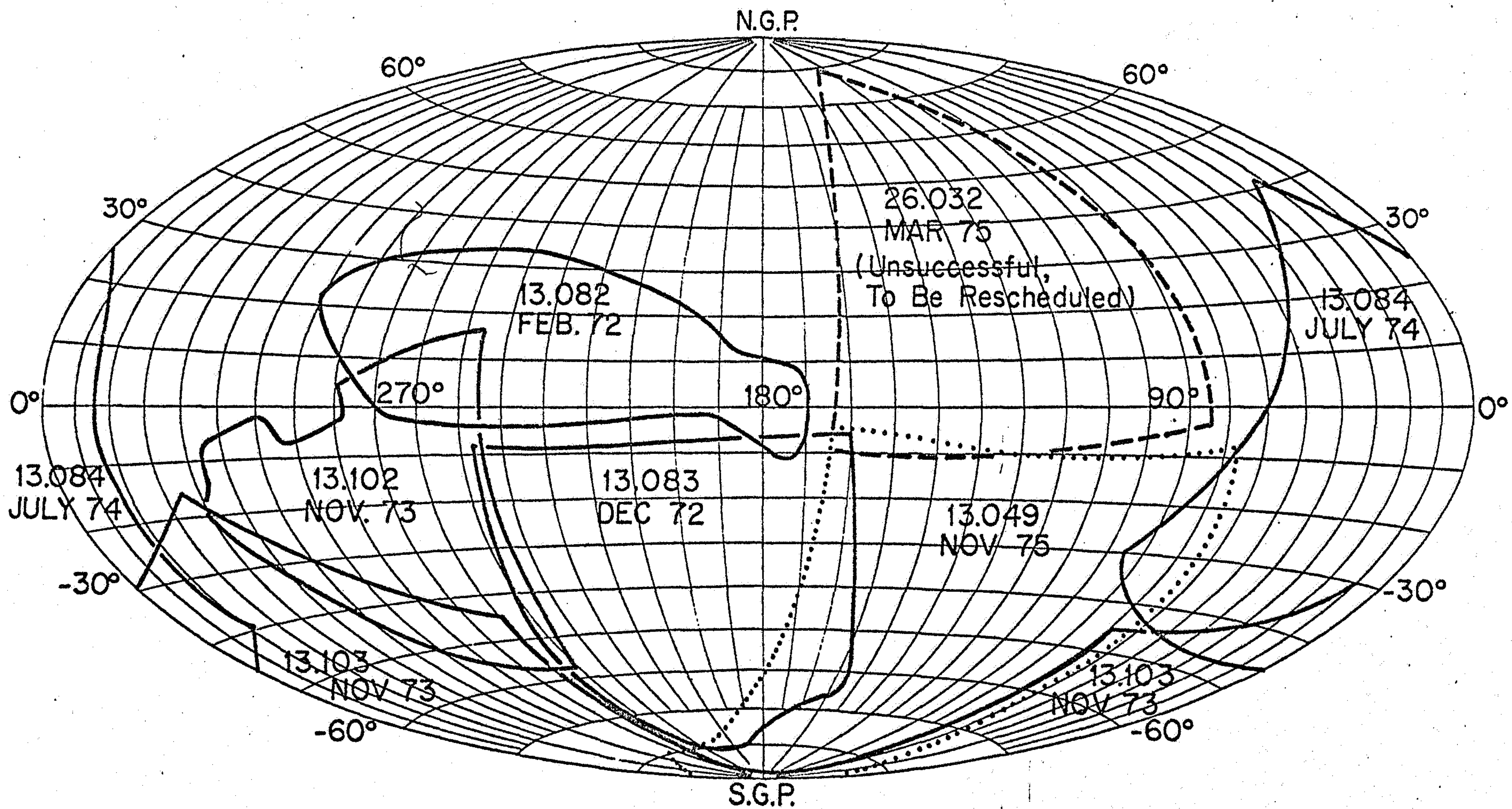
I. ROCKET X-RAY INVESTIGATIONS

Aerobee 170 flight 13.049 UH was launched successfully from White Sands, 8 November 1975. The X-ray instrument was the same as flown on 13.103, 13.084 and 26.032. All systems performed perfectly and the data are being reduced and analyzed.

Aerobee 200 flight 26.032 launched 7 March 1975 provided no data because of a failure in the coaxial cable that carries the r.f. from transmitter to antenna. We have completed the aspect solution for this flight using the star field photographs and find that the control system performed correctly. These data have been forwarded to the sounding rocket branch at Goddard. There is nothing more we can do with the results of this unhappy venture. A thorough investigation was carried out by Goddard personnel and steps have been taken by them to ensure no recurrence of the fault.

Figure 1 shows an all-sky map in galactic coordinates of the areas covered to date in our survey of diffuse soft X-ray features.

The analysis of the data from these flights has not proceeded as fast as we originally hoped. Small differences in the X-ray transmission of the counter windows, differences in the composition and pressure of the counter gas etc. all contributed to finite differences in the instrumental sensitivity or factors to be used in converting counting rates to absolute intensities. Our aim is to produce composite maps of the sky in the three broad energy bands defined by a boron window counter ($E<180$ eV), a carbon window counter ($E<280$ eV), and the region 500 to 1000 eV. Unless extreme care is taken in the normalization procedure, artificial gradients of intensity can be produced along the boundaries of adjacent sets of data.



N.G.P.
60°
60°
30°
30°
26.032
MAR 75
(Unsuccessful,
To Be Rescheduled)
13.082
FEB. 72
13.084
JULY 74
0°
270°
180°
90°
0°
13.084
JULY 74
13.102
NOV. 73
13.083
DEC 72
13.049
NOV 75
-30°
-30°
13.103
NOV 73
13.103
NOV 73
-60°
-60°
S.G.P.

Figure 1

A composite map of the carbon band data from flights 13.082, 13.083, 13.102 and 13.103 (flown from Australia) is shown in figure 2. The coordinate system is galactic, the same as used for figure 1. A zero-th order deconvolution of the detector field of view has been incorporated. Each 2° x 2° element of sky is assigned an intensity equal to the counting rate of the detector weighted by the collimator response to that piece of sky, summed over all exposures during the several flights. Since the sky coverage is non-uniform, some regions have more exposure and hence better statistical accuracy than others. But on the average the counters correspond to a 1.5 to 2σ difference in intensity. The most prominent features of this map are:

1) The Vela supernova remnant which is not part of the diffuse background and should be ignored for this discussion.

2) The emission feature at (195, 15) is the Gemini hot spot first seen by us in 1971 and since then by a number of observers.

3) At (205, -40) is the Eridanus hot spot, also previously seen.

4) This ridge along longitude 240 was reported in Williamson _et al._ (1974) and confirmed by the Australian data.

5) A new feature is the ridge along latitude -60° running from longitude 240 to 300 where it joins

6) a new enhancement in the constellation Tucana at (330, -50) and

7) a new enhancement in the constellation Piscis Austrinus at (20, -50).

8) Another enhanced region in Telescopium is evident between longitude 300 to 360, latitude -15 to -40.

There are also apparent two regions of low emission, one at (70, -45) and the other a large 30° diameter region around (290, -15). A comparison

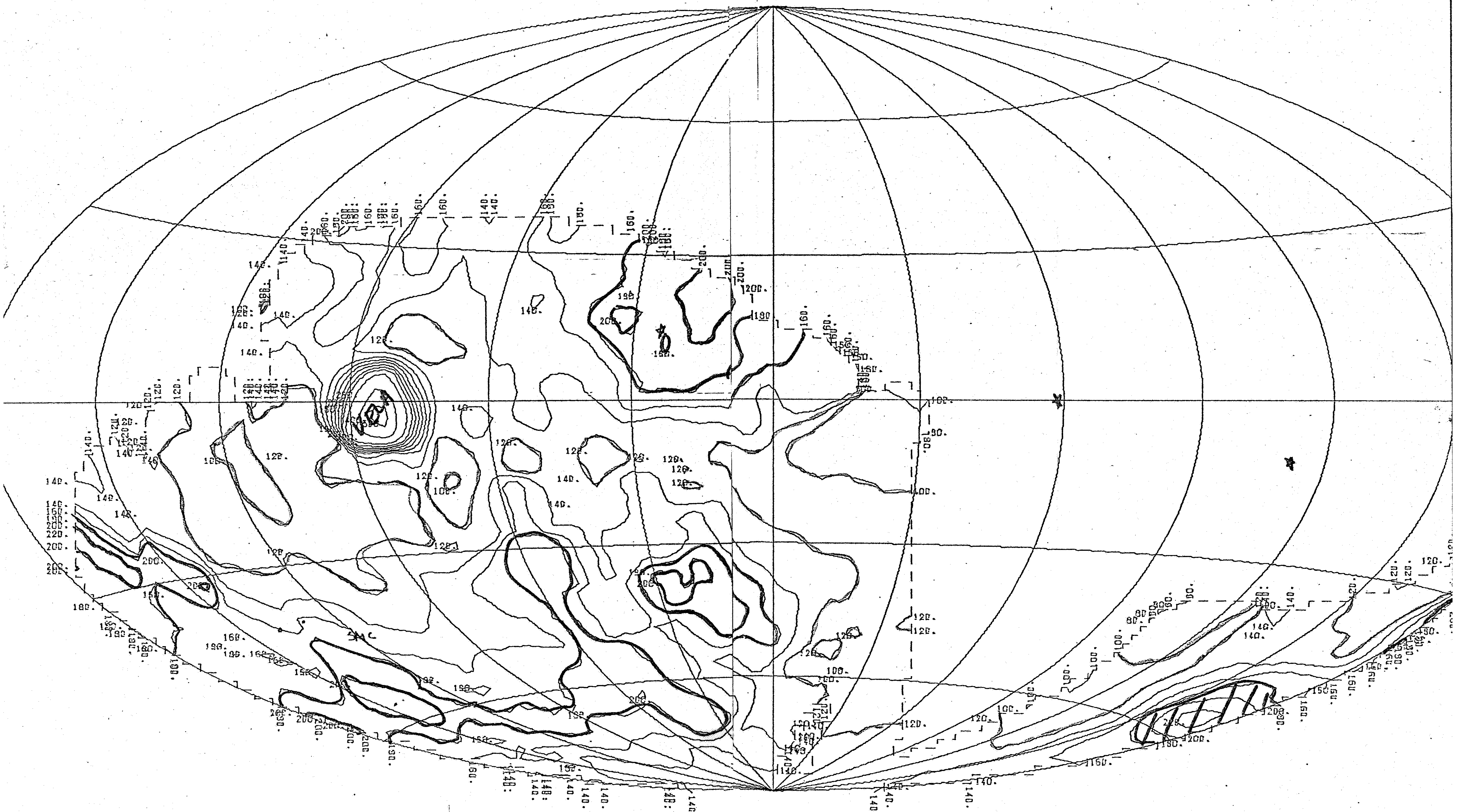


Figure 2

of this map with the radio continuum map of Landecker and Wielebinski at 150 MHz shows no clear pattern. Some regions exhibit a positive correlation and some a negative correlation.

The relationship of the soft X-rays to 21 cm hydrogen column density measurements is more interesting. It has long been apparent that in general, soft X-rays are enhanced where the neutral hydrogen is lacking. This led many observers to postulate on extragalactic origin for the soft X-rays. But it has since been noted that the soft X-ray intensity variations across the sky do not correspond quantitatively to what one would expect from absorption. Nor does one observe the spectral variations with intensity that one would expect from absorption. A better explanation of the correlation between low N_H and high X-ray intensity is that the lack of neutral hydrogen as well as the enhancement of soft X-rays both result from the same cause, specifically the interstellar medium is laced with the remnants of old supernovae.

The pattern of high X-ray emission being associated with regions of low N_H is also seen in this new data, except for the Telescopium hot spot where the N_H is not particularly low. Otherwise, the regions of the ridges and the Tucana and Riscis Austrinus hot spots are characterized by as small values of total N_H as are observed anywhere on the sky. Furthermore, N_H is relatively high through this low region (290, -15), along the plane, down longitude 160, and over to (70, -45).

Perhaps the most intriguing N_H feature appears in the (unpublished) narrow velocity-width HI maps of Heiles and co-workers. In several successive velocity cuts there stands out very clearly a complete ring of neutral hydrogen, 20 to 30 degrees in diameter, surrounding the Eridanus hot spot. Furthermore, the ring has increasing size in successive velocity intervals, indicating that the ring is expanding. Verschuur also has observed a portion of this ring and concludes that it probably indicates the existance of an old, nearby, supernova shell. Heiles' narrow velocity maps also show HI filaments extending up from the plane on either side of the Gemini hot spot. They do not form a complete loop, but are still suggestive of a supernova origin. Maps of boron and M band data for this region show essentially the same spatial features as this map except that the region from Telescopium to Vela is more enhanced in the M band (it is anomolously hard) and the ridge across -60° is slightly more pronounced in the boron band (it is anomolously soft).

As for the effective temperatures implied by these data, we have tried fitting the pulse height spectra in the various counters both from high latitude and low latitude features, both in the optically thick and optically thin cases. We used both a simple exponential bremsstrahlung model and complete line plus continuum program of Raymond, Smith, and Cox. We find:

1) Fitting only boron window data implies that the X-ray spectrum is very soft - temperatures of 300-500 thousand degrees.

2) Fitting only data less than 400 ev but using both carbon and boron yields somewhat higher temperatures, 500-800 thousand degrees.

3) Fitting all the data up to 1000 ev requires temperatures of two to three million degrees, but an acceptable fit (using χ^2) cannot be obtained with a single temperature.

This leads to the tentative hypothesis that the soft X-ray diffuse background seen in any direction is produced by several regions of hot interstellar material with temperatures ranging from 3×10^5 to 3×10^6 K, probably formed by overlapping old supernova shells.

II. LABORATORY DEVELOPMENTS

a) X-Ray Calibration Beam Apparatus. The new apparatus described in the last progress report has performed more or less satisfactorily. The ion pump-molecular sieve combination is really too slow to keep up with the Henke tube outgassing at high power levels. As a result we sometimes run at too-high pressures and have had some carbon build-up on the beryllium anode.

We have added a 20 foot length of commercial plastic sewer pipe to provide a broad but narrow angle beam for Bragg crystal studies. A newly-designed gate valve has been constructed and installed. It permits the Henke tube with its ultra-high vacuum pumps to be sealed off from the diffusion pumped portion of the system, or with a simple twist of a handle, permits a very thin soft X-ray transmitting window to separate the two sections.

b) Developments Related to Soft X-Ray Diffuse Spectrometry. Even if our pending Explorer proposal for a Bragg spectrometer to investigate spectral line studies of the soft X-ray background is not approved, we feel that the measurement must ultimately be done. We have therefore proceeded with several investigations crucial to that program.

i) Position Sensitive Proportional Counter. The Bragg spectrometer device requires position sensing over an approximately 20 cm long counter to 0.5% or about 1 mm to achieve $\lambda/\Delta\lambda \geqslant 100$.

A gas filled position-sensitive proportional counter (PSPC) using resistance position encoding has been constructed and is currently being investigated. The construction of PSPCs is characterized by its simplicity when compared with solid state counters and multiwire systems using delay

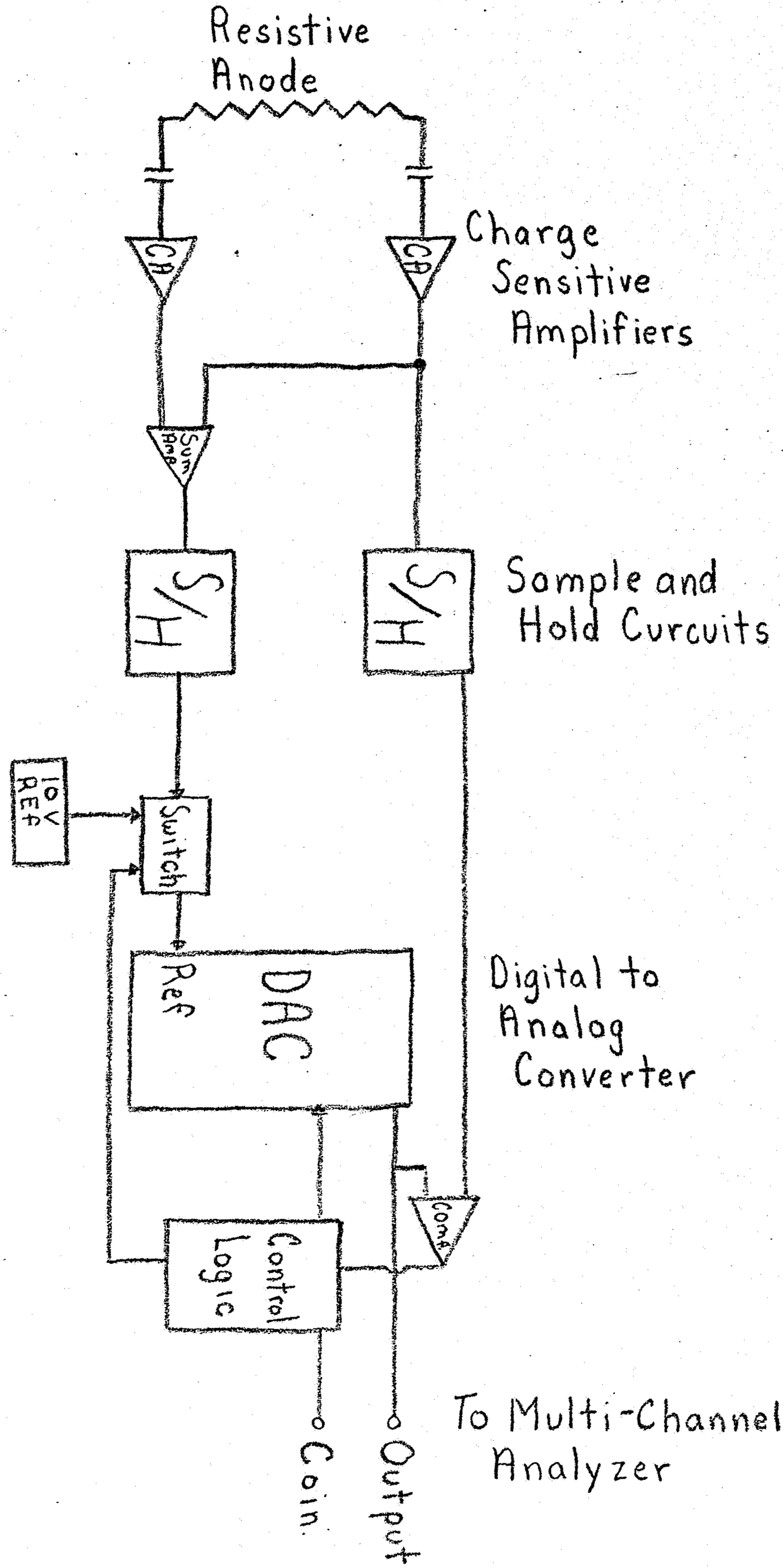

Resistive Anode
CA
CA
Charge Sensitive Amplifiers
Sum Amp
S/H
S/H
Sample and Hold Curcuits
10V REF
Switch
Ref
DAC
Digital to Analog Converter
Comp
Control Logic
Coin.
Output
To Multi-Channel Analyzer

Figure 3

lines. The counter differs from conventional proportional counters in the use of a resistive anode and the requirement that both ends of the anode be accessible as signal output terminals.

The counter constructed has a 210 mm active length using a carbon coated quartz fiber with a resistivity of 8.9 Kilo-ohms/mm as the anode. The face of the counter was covered by a slit collimator comprised of 195 slits 1.08 mm apart and 0.25 mm in width. The channel length of the collimator is 50.8 mm and sits flush against the window which is 30 mm in front of the anode. It has been operated thus far with P-10 at atmospheric pressur using an Fe^{55} (5.9 Kev) source.

The signal from both ends of the anode is fed to separate charge-sensitive amplifiers, and the outputs added. After processing by conventional sample and hold circuits, the combined signal is used as the reference for a 10 bit DAC. A comparator, through a series of flip-flops, compares the output of the DAC with the signal from one of the charge amps. The required number of bits are turned on to produce identical signals from the charge amp and the DAC. The reference to the DAC is then switched from the combined signal to a 10 volt supply and the output of the DAC is read by a multichannel analyzer.

At the moment, we have only obtained an upper limit for the resolution of the PSPC. This is exhibited in the photograph where the FWHM of the peaks are $\sim$ 2 channels or 0.5 mm, about a factor of 2 better than our design goal.

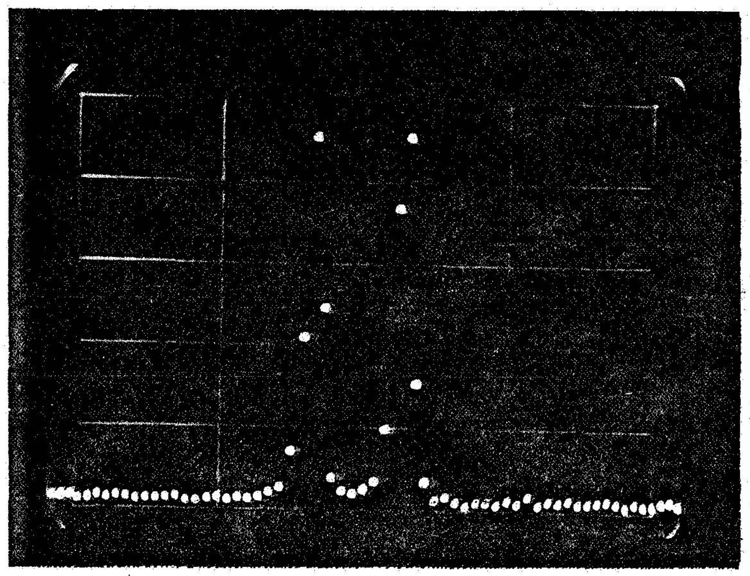


Figure 4

<u>ii) Lead Stearate Substrates.</u> At the present time, curved glass plates on which lead stearate is deposited are formed by placing flat float glass on a curved steel fixture and allowing the glass to sag in an annealing oven until it assumes the shape of the fixture. The existing fixture was formed by rolling flat stock and incorporates several welds. Although crude, it has been adequate for the purpose of evaluating this glass-forming technique. In order to assess the results, the profiles of several plates were measured using apparatus illustrated in figure 5. A laser is directed at the plate by reflecting it off of a small rotatable mirror placed at the center of curvature of the plate. The reflected beam is separated from the incident beam by means of a beam splitter placed ahead of the laser. The angular deviation $\delta\theta$ from uniform curvature is related to the linear δS (from center reference) at the screen by $2L\delta\theta \approx \delta S$ where $L = a+b+c$. A trace from a typical plate (15 cm x 5 cm) is shown in figure 6. The x and y components of δS provide a direct measure of the curvature of the plate in the long and short dimensions respectively.

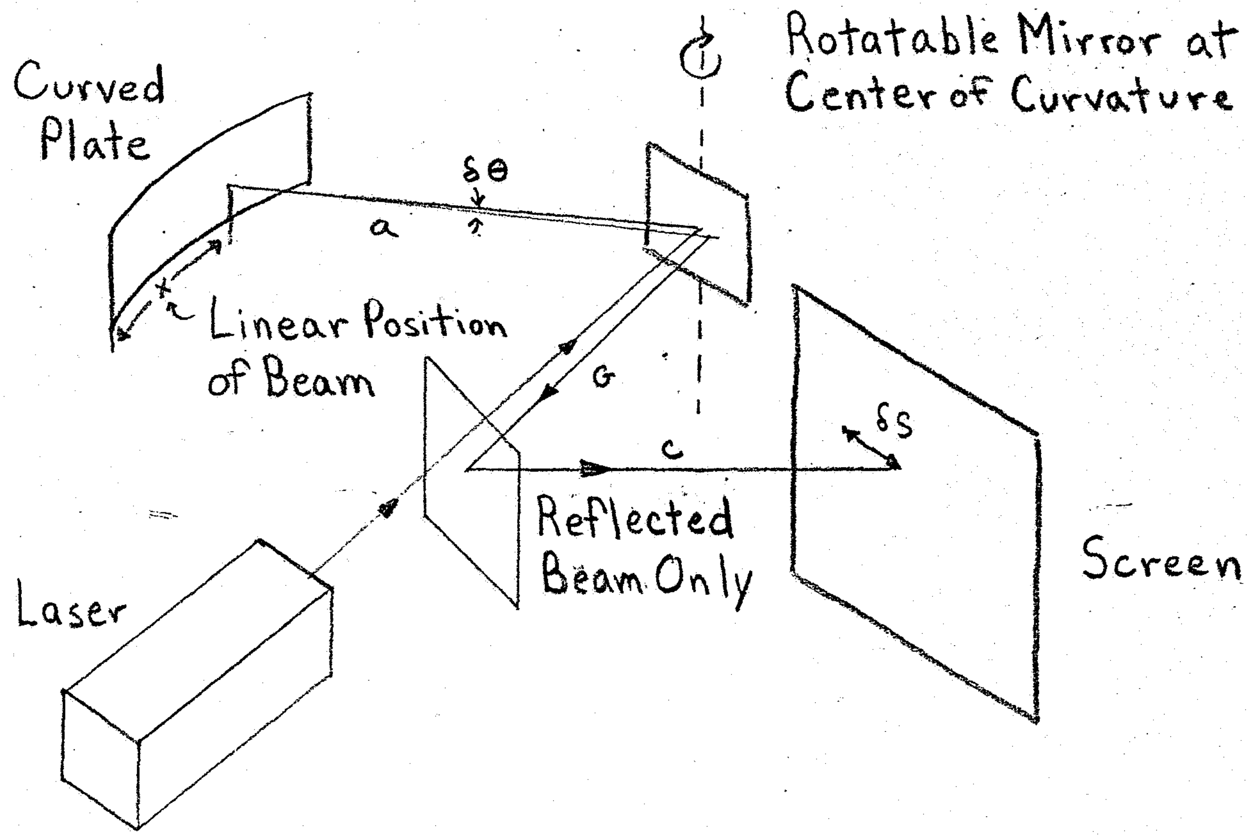

Rotatable Mirror at
Center of Curvature
Curved
Plate
δθ
a
x
Linear Position
of Beam
b
c
δs
Reflected
Beam Only
Screen
Laser

Figure 5

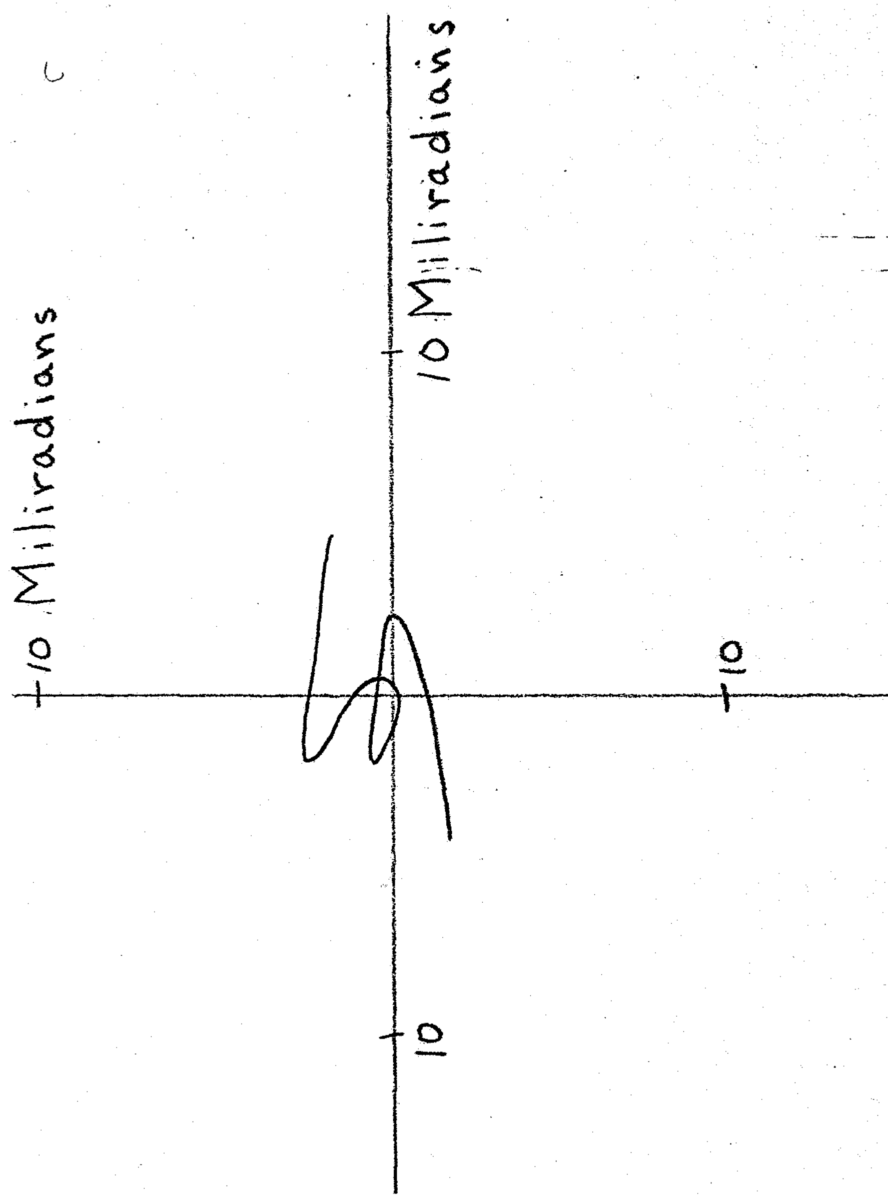
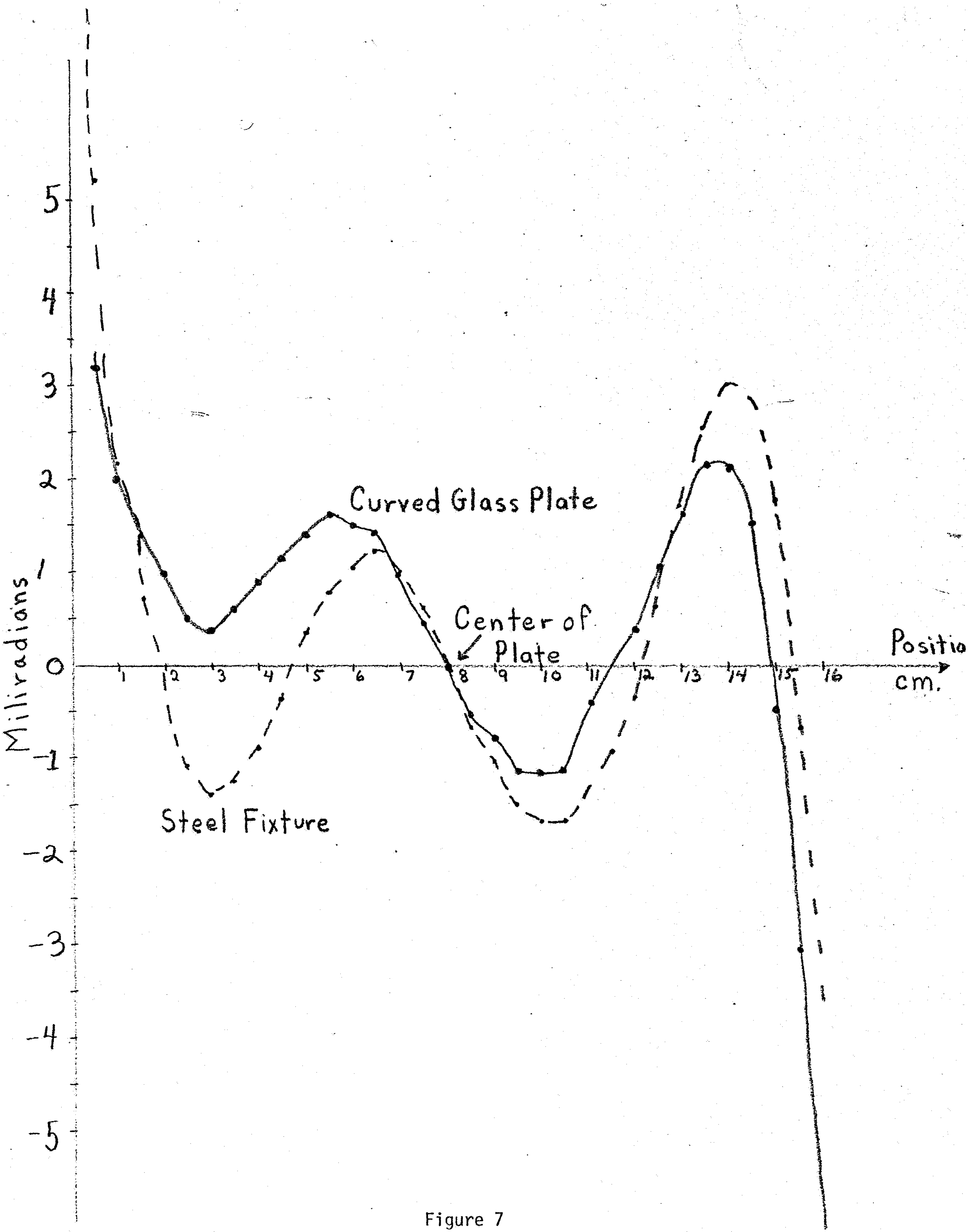


Figure 6



Milliradians
5
4
3
2
1
0
-1
-2
-3
-4
-5
Curved Glass Plate
Center of Plate
Steel Fixture
Positio
cm.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Figure 7

Figure 7 is a plot of the deviation (from a circle of 73.25 cm radius) of a typical plate. Also shown (broken line) is a similar plot for the steel fixture. The large irregularities in the surface of the fixture demonstrate that the method used to shape the fixture is not adequate. However, it is apparent that the profile of the glass plate tends to conform to that of the fixture and it would seem that this technique for curving the glass can be used.

A new fixture is being constructed which will have a machined surface and will not be welded. It is expected that this will eliminate the irregularities now present in the profiles of the substrates.

III. THEORETICAL STUDIES OF SHOCK WAVES AND ASTROPHYSICAL PLASMAS

a) Galactic Infall. A revised manuscript was submitted to Ap.J. and was accepted for publication in January.

A very considerable amount of effort was spent on the time dependent problem and several exchanges of letters and results took place between Cox and Roland Hunt, at the time of Oxford University, but recently moved to the University of Strathclyde in Glasgow, Scotland. This exchange was very productive, leading to a significant improvement of understanding of the development of the flow. The effort ground to a halt during the past semester but is now being resumed. It is my present expectation that one of the first really useful papers on galactic infall will come out of this exchange.

b) Quasi Stellar Sources. Revisions were completed by Cox in Madison and Mac Alpine at Michigan, but are still underway on Daltabuit's part in Mexico.

c) Cosmic Ray Acceleration. This effort remains as previously described. Paper I is a complete manuscript, paper II is in rough draft. A new research student, David Hedrick, has undertaken a review of the processes in the second paper as his first project and Cox has accepted an invitation to give an Astrophysics Seminar on the work at the University of Chicago in late February. The essential result of this work is that a modest amount of interstellar acceleration may be taking place, but full operation of such processes would produce consequences which apparently violate observational results.

d) Large Scale Effects of Supernova Remnants. The simulation of interacting supernovae in the interstellar medium by B. Smith was completed, his thesis written, and his degree awarded in October. He has since gone to Goddard Space Flight Center and has there prepared a manuscript on this work.

A little more work has taken place on the tunnel wall boundary in order to estimate the temperature distribution function which one might expect for the soft X-ray background. P. Burstein of the experimental group is presently preparing to compare these distribution functions with the observed background.

A first attack has been made on the problem of ISM heating by the acoustical noise generated in the tunnel system. The results are promising and suggest that a more extensive investigation should be made. In the last report we speculated that this could be the long-sought heating mechanism for normal interstellar material.

e) Line and Continuum Radiation. The paper on the total and elemental cooling rates has been accepted for publication in Ap.J. in early 1976. The preparation of the equilibrium spectra paper is nearly complete and it is anticipated that it will be submitted to Ap.J. by February 1976. The shock program revisions are substantially complete; the revised program has been run for a few test cases and it is performing well. Certain decisions remain about how to suitably carry out the radiative transfer, and how to select a suitable grid of parameters for the families of shock spectra which will be calculated. It has already been learned that the new spectra will differ from the earlier results (of Cox) for the same choice of parameters, and that these rather significant changes will represent a closer approximation to reality. It is hoped that these changes and reasons for them can be prepared into a first paper in February. This would be followed by X-ray and EUV spectra of a grid of fast shockwaves, probably in March or April. Finally a complete low velocity grid with optical spectra for comparison with interstellar shockwaves should be ready in late spring or early summer. The bulk of the work on this project is being carried out by J. Raymond.

STAFF

Professors	Donald P. Cox William L. Kraushaar
Associate Scientist	Alan N. Bunner *
Assistant Scientist	Richard J. Borken *
Research Assistants	Paul Burstein Peter Fried DeAnn Iwan * John Nousek * John Raymond Wilton Sanders Barham Smith David Trivett
Specialist	James Morrison
Secretary	Karine Brager **
Hourly Students	Paul Anderson Brad Eltman Martin McLaughlin David Schumann Gayle Sugiyama James Sowinski Steven Weibel

* Supported totally by OSO-I contract NAS5-11361.

** Supported in part by UW Physics Department and NASA grant NGR 50-002-162.

TALKS (CALENDAR YEAR 1975)

W. Kraushaar, "Is There A Hot Interstellar Medium", Astronomy Colloquium, University of Minnesota, January 23, 1975.

D. P. Cox, "Large Scale Effects of Supernova Remnants on the Galaxy", talk given at Kitt Peak National Observatory, January 1975.

D. P. Cox, "Large Scale Effects of Supernova Remnants on the Galaxy", talk given at Lick Observatory, University of California Santa Cruz, January 1975.

B. Smith, "The Structure of the Interstellar Medium", colloquium given at University of Maryland, College Park, January 1975.

W. Kraushaar, "Is There A Hot Interstellar Medium?" joint physics and astronomy colloquium, University of Illinois, February 6, 1975.

J. Raymond, "Radiative Cooling of a Hot Plasma", paper presented at AAS meeting, Bloomington, Indiana, March 1975.

B. Smith, "Structure of the Hot Regions in the Interstellar Medium", paper presented at AAS meeting, Bloomington, Indiana, March 1975.

D. P. Cox, "And on the First Day ...", public lecture of the UW Madison Physics Department, March 1975.

B. Smith, "Exploring the Structure of the Interstellar Medium by Simulation Techniques", colloquium given at National Radio Astronomy Observatory, Charlottesville, Virginia, April 1975.

W. Kraushaar, "Is There a Hot Interstellar Medium?", physics colloquium, University of Wisconsin, April 18, 1975.

R. Borken, "A Soft X-Ray Spectrometer for Diffuse X-Rays", Symposium on the Techniques of Solar and Cosmic X-Ray Spectroscopy, Mullard Space Science Laboratory, England, May 22-23, 1975.

W. Kraushaar, "The Interstellar Medium", Physics Colloquium, Duke University, November 5, 1975.

D. P. Cox, "Ecology of an Island Universe", public lecture at the High School Science Symposium of the University of Northern Iowa, November 1975.

D. P. Cox, "Large Scale Effects of Supernova Remnants on the Galaxy", astronomy colloquium, Yerkes Observatory, November 1975.

J. Raymond, B. Smith, and D. P. Cox, "X-Ray Spectrum of a Hot Plasma", paper presented at AAS meeting, Chicago, Illinois, December 1975.

J. Raymond and D. P. Cox, "Theoretical Models of Interstellar Shock Waves", paper presented at AAS meeting, Chicago, Illinois, December 1975.

W. Sanders, "Observations of the Soft X-Ray Diffuse Background, paper presented at AAS meeting, Chicago, Illinois, December 8, 1975.

J. Raymond, "Shockwave Heating of the Interstellar Medium", colloquium given at Los Alamos Scientific Laboratory, November 1975.

PUBLICATIONS (CALENDAR YEAR 1975)

Cox, D. P. and Smith, B. W., "Accretion by the Galaxy: Effects of Radiative Cooling on the Flow Structure and Infall Rate", The Astrophysical Journal, in press.

Raymond, J. C., Cox, D. P., and Smith, B. W., "Radiative Cooling of a Low Density Plasma", submitted to The Astrophysical Journal.

Vanderhill, M. J., Borken, R. J., Bunner, A. N., Burstein, P. H., and Kraushaar, W. L., "A Search for Stellar Soft X-Ray Sources", Ap.J. Letters, 197, L19 (1975).

Williamson, F. O. and Maxson, C., "Thin Films for X-Ray Astronomy", Rev. Sci. Instr. 44, 418 (1975).

Borken, R. J. and Kraushaar, W. L., "A Soft X-Ray Spectrometer for Diffuse Cosmic Sources", Space Science Instrumentation, in press.

McCammon, D., Meyer, S., Sanders, W., and Williamson, F., "Neutral Hydrogen in the Direction of the Small Magellanic Cloud and the Limits on an Extragalactic Soft X-Ray Fluz", submitted to The Astrophysical Journal.

Smith, B. W., "Theoretical Models of Processes Producing Thermal Soft X-Rays in the Interstellar Medium", Ph.D. Dissertation, Department of Physics, University of Wisconsin, Madison, October 1975.

PRELIMINARY C-BAND MAP